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Schematising activities in early childhood education

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The purpose of this study was to determine the importance of introducing schematising to children in early childhood and to determine whether schematising can be taught to children. This was done using a longitudinal, quantitative study with a quasi-experimental design ($N = 133$). In this study, the use of schematising was taught to an experimental group of children to determine if it is possible to realise significantly improved results in schematising tasks for an experimental group in comparison to a control group of children who were not taught schematising. Pupils in the experimental group demonstrated significantly better results on schematising, which cannot be explained by maturation. In our future research, we will investigate the mathematical performances of these experimental and control groups in the next grade of the primary school curriculum.

Keywords: schematising; mathematics; early childhood

Background of the study

Many researchers recognise the difficulties children experience in mathematical understanding. Detailed descriptions are made about the possible origins of these problems (see, e.g., Hughes, 1986; Siegler & Booth, 2004; Torbeyns, Verschaffel, & Ghesquière, 2004). Often, the reason is attributed to children's lack of prerequisite abilities. For the development of these abilities, young children are regularly instructed to make preparatory mathematical tasks in Grade 2 (Dutch school system, 5-year-olds). Most of the time, these tasks are basically quite similar to tasks in Grade 3, but presented in a less formal way or at a lower level of complexity. This practice is generally supposed to better prepare children for mathematical education in Grade 3 and beyond.

In the present study, another solution for children's problems in mathematical understanding was investigated. We supposed that the reason for those problems might be related to problems in the transition from concrete practical thinking in Grade 2 to more formal symbolical thinking in Grade 3. Children at the age of 5 to 6 are not accustomed to thinking at an abstract-formal level. They do not think by means of representations such as symbols and schemes which are frequently presented in mathematics education. Besides, children are not aware of the function of these representations. Young children are not accustomed to abstract representations: If I see three apples, then I draw three apples, not the numeral 3.

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If I find two more apples, then I draw two more apples, but I do not represent this as “ $3 + 2 = 5$ ”. Doing such formal assignments requires ample experience with the invention and use of symbols in meaningful contexts. This often does not happen in current mathematics education, and, therefore, mathematics education needs to be improved.

Several authors already called for the improvement of early mathematics education. Stern, for example, argues for the strengthening of understanding (rather than mastery of technical operations): “Mathematics is known to be hard to teach and difficult to learn. It is well known many students never get real insight into important aspects of the subject” (Stern, 1997, p. 239). Similarly, Carruthers and Worthington (2003) have argued for promoting understanding in young children’s mathematical actions. They described the problem with learning mathematics as a translation problem between children’s own informal representational graphics and later abstract symbolism. They claim that it is crucial for teachers to recognise and develop children’s own representations because, in doing so, teachers will be able to help children to make the translation to formal mathematical symbolism (Carruthers & Worthington, 2003). With these findings as a basis for our approach, we decided that it was reasonable to introduce schematising strategies to children to help them build this bridge between informal and formal mathematics. From a review of the literature, we found that this has never been investigated (see Poland, 2007).

The study described here was the first step in our research project. It was believed that this could expand our understanding of schematising and its potential benefits. We expected to find differences between the results of students who participated and were successful using schematising activities as compared to the children in the control group. Although Van Oers (1994, 1996) demonstrated that schematising activities are accessible to young children, it is not clear if this can be improved by education. Venger (1986) found evidence to support the theory that such a semiotic activity can be taught. However, in his study, control groups were not used. As a result, we initially did not exclude the possibility that schematising is a product of general cognitive development. In order to determine if learning to schematise impacts mathematical development, we had to find groups of young children that differed significantly with regard to the ability of semiotic activity (schematising). As we did not expect to find such a group, we invested a year in creating experimental groups which were likely to perform significantly better on schematising. In essence, we attempted to teach this in early childhood education in the context of play activities. The current article describes this part of our research project in which we determine if it is possible to create a schematising group through educational strategies. The research question developed from this reasoning was:

Is it possible to teach children in early childhood education schematising skills in the context of their play activities?

Theoretical framework

The importance of schematising activities

Making graphical representations is an important feature of mathematics education. Using self-made representations, children can learn how to reflect on what they have done and what they were meant to do. They therefore learn to represent

relationships between objects (things, numbers, variables, etc.) using schematisations. These schematisations give structure to their thoughts and provide a means for the child to communicate mathematical reasoning.

One of the capabilities that a 5-year-old child demonstrates is giving meaning through drawing (Matthews, 1999). This is a prime example of a schematising activity (Van Oers & Wardekker, 1997). A schematising activity is every cognitive activity accomplishing the construction and improvement of symbolic representations of an element of the physical and sociocultural reality. This is completely different from Piaget's definition of the concept of "schema" (Piaget, 1952; see also Ginsburg & Oppen, 1969, p. 21). Piaget defined a schema as the mental representation of an associated set of perceptions, ideas, and/or immanent structure of actions. We define a scheme as a simplified structured representation, description, or imitation of a part of the sociocultural reality. A scheme always comprises a structure that is a construction of several symbols representing a part of reality. A scheme always assumes a structural similarity between the scheme and what it represents. "Schematisations form the bridge between the concrete practical thinking of young children and logical-symbolical thinking in later development. This bridging function as attributed to schematising is an important argument in favour of schematising in early childhood" (Dijk, Van Oers, & Terwel, 2004, p. 75). By using schematisations, children can be provided with the opportunity to make a graphical representation of their view of reality and bridge the gap we mentioned earlier.

Reflecting on the relationship between drawings and their meanings is a "thinking activity" (Van Oers & Wardekker, 1997, p. 196). This reflection, however, is not as simple as it appears. It is not simply a matter of telling a child to "just explain what you saw or drew". The process is slightly more complex. One must know what kind of schematisations can be used to demonstrate what one wants to portray. Additionally, a child must be able to reflect on whether the symbols it has chosen really express its intended message.

In early childhood, children rarely use written symbols or schemes to represent their thoughts. However, as they grow older, they are required to use this form of notation more frequently, especially with respect to mathematics activities. This notating is what Pimm (1987) calls "recording". Pimm recognises children's problems in mathematics education and mathematical reasoning. He wrote, "Pupils frequently fail to have a clear idea of why they are recording and, without any feeling for the purpose, it is difficult to discover what, for example, is ambiguous or insufficient in some way" (1987, p. 137). Children often do not understand why they have to use this mathematical language full of difficult symbols and imperceptible relationships. They are thus unaware of the multiple functions of symbols. According to Pimm (1987, 1995), we can attribute at least two main functions to symbols:

- (1) Communication: Through symbols we can communicate.
- (2) Thinking device: Symbols support "problem-solving". By reinterpreting a symbol, or by notating it in another more familiar way, we can make the problem recognisable.

Evidently, we are able to reflect through the use of symbols. "It is largely by the use of symbols that we achieve voluntary control over our thoughts" (Skemp, as

cited in Ruckstuhl, 2001, p. 15). It is desirable that children learn to manage their thoughts in later development (from the age of 7 onward), but this is not an easy process. Children in early childhood are familiar with working with visible objects and relationships. However, in mathematical education, they suddenly have to work with invisible objects and relationships. These objects and relationships have to be represented by symbols. Thus, pupils need to learn to work with representations using symbols and schemes. Pape and Tchoshanov (2001) propose that representations are an important feature of mathematics.

Consequently, according to Pape and Tchoshanov (2001), in mathematics education, representations must be thought of as tools for reasoning, explaining, and justifying. Educators should teach children the function of these tools. It is necessary to develop children's understanding (Abrantes, 2002) by introducing tools to help them in this process of development. Self-invented schemes built on self-invented notational systems are the tools we want to initiate. By allowing children to express their thoughts in their own ways to begin with, we use already existing symbols cemented to their own conceptual structure (Skemp, 1989, p. 103).

The treasures of cultural tools

The theory and research described in this article are based on the Vygotskian approach to human development. We start by explaining the Vygotskian cultural-historical theory as it applies to mathematics education (Van Oers, Wardekker, Elbers, & Van der Veer, 2008; Vygotsky, 1978; Wertsch, 1987).

From a cultural-historical point of view, the development of mathematical thinking can be conceived of as a process of appropriating cultural (mathematical) tools. Many children have difficulties with appropriating these tools and the correlated forms of mathematical reasoning. These problems usually manifest themselves as soon as children reach Grade 3 (age 6 to 7) in primary school, because, at that point, there is a qualitative change in children's activities and even in the way they are taught and how they learn. In early childhood, children do not have to organise their knowledge and thoughts in the same way they organise them in later development. According to El' konin (1972), as children age, different interests and capacities emerge. He theorises that development can be classified into five periods spread over the years from birth to 16 years of age. At different stages in its development, a child relates differently to its environment. Additionally, he contends that specific capabilities and interests are characteristic for a child in a certain stage, including its ways of communicating and representing. In the Vygotskian perspective (Vygotsky, 1978), a stage is defined as a specific system of functions like thinking, memory, emotions, and language. As a result of this system of functions, each child has its own characteristic relationship with the cultural environment. Within these stages, certain tensions exist because, at a certain point, a child becomes ready to develop new skills which are not characteristic of the stage of development it is in at that moment. The tensions result from the desire to use the skills that are characteristic to the next stage of development. In essence, there are tensions between what a child wants to do and what it is able to do on its own. The characteristic form that a child uses to interact with its environment at a certain stage in its development is what is called the "leading activity".

For children between the ages of 3 and 7, the leading activity is play. When a child is approximately 7 years old, a discrepancy arises between the things a child

wants to do and the things it can do. This discrepancy can only be solved by introducing elements from the next stage of development. "This crisis is the psychological motor of development" (Van Oers & Wardekker, 1997, p.193). As young children's *play* develops, it changes into a new leading activity around 7 years of age: *Learning* becomes the next leading activity. In this period, a foundation for later constructive learning is formed. This is a type of directed learning that is based on the use of models and schemes and on discussions regarding their meaning (Davydov, 1972/1990). In this phase, children are motivated enough to get involved in a form of "learning to know" (Van Oers & Wardekker, 1997) and also conceptualise concrete reality in terms of abstract models. In the words of Davydov (as cited in Van Oers & Van Dijk, 2004, p. 53): "In this period children are trying to ascend from the abstract to the concrete." According to Davydov, abstract symbolic models are the best means of moving from the abstract to the concrete.

According to the theory of leading activities, finding strategies for promoting new learning processes in early childhood education that can promote the emergence of the next leading activity, is imperative (Van Oers, 1994). The roots of learning processes that will play a leading role in later development are found in the context of children's play. In play activities, children also learn to communicate and coordinate their own activities. In this phase, children can learn to deal with schematical representations of an element of reality, such as schemes, diagrams, drawings, or symbols. In this period, it is possible to lay a foundation for later conscious, constructive learning (Van Oers & Wardekker, 1997, pp. 192–193), that is, learning activity. The acquisition of strategies to incorporate schematic representations into mathematical reasoning is presumably an important element of this foundation.

Vygotsky emphasised the fact that a teacher should build on a child's own interests and capabilities as a starting point for further development and, in doing so, try to convert these elements into a new form (Vygotsky, 1926/1997, pp. 82–83). Therefore, educational instruction should slightly exceed a child's development (see Vygotsky, 1978). It should offer children the tools needed to create new and familiar ways of thinking and communicating. This so-called "Developmental Education" attempts to stimulate a child's development by enriching its activities and by starting from its own capabilities, especially with regard to its ability to use symbols and language. To enhance their symbolic capabilities, we can encourage children to invent graphic representations to communicate their thoughts and ideas. As Carruthers and Worthington (2003) state, "children's own mathematical graphics supports children in developing their competences" (p. 78). Early childhood education should therefore assist children to improve these schematisations (including notations and schemes). The use of schematical representations could be a very important strategy for improving this process. As early as the *play stage of development*, we should attempt to enrich their play activity with schematisations. This can provide children with a rough understanding of the function of symbols and schemes so that they can be used when children encounter formal mathematical symbols in the later stages of mathematical reasoning. Consequently, from a cultural-historical point of view, early childhood education can be improved by introducing the tool of schematical representations and assisting the children to discover the hidden potentials (treasures) of these tools for the solution of (mathematical) problems.

An example of schematising is as follows: Imagine a play activity where a child is building a racetrack out of blocks. Another child has already built his own racetrack

and proceeds to draw a map of the racetrack to show his little brother and re-create the racetrack at home. The first child is very interested in the second child's schematising activity and wonders if, and how, he could map his racetrack too. Unfortunately, he does not know how to start and therefore asks the teacher for help. The teacher in turn asks the child how he planned and executed his own racetrack, how many blocks he used, and so on. By doing this, the child can learn to reflect on his activity and also learns how his play can be enriched by introducing a schematising activity. By asking for help, the child indicates that he is ready to develop some new skills and that he is motivated to learn because he participated in a meaningful activity. By enriching this activity through the introduction of a new tool, the child can learn how to give more meaning to what he has done or wants to do. He thus also learns how to create a graphical representation of his meaningful activity in his own unique way.

Schematising: static or dynamic?

According to the Vygotskian point of view (Vygotsky, 1978), it is important to teach children mathematics with an appreciation for their own capabilities and interests. Using this appreciation as a starting point, the next step is to introduce the tools that will enrich their activities and allow them to take the subsequent step to further improve their learning outcomes. As demonstrated, we have a strong theoretical basis for our assumption that the introduction of schematising is a good way to help children with the difficulties surrounding mathematics and to improve their learning processes and learning outcomes.

In order to ensure that the research results following from the video analysis of our "schematising test" are clearly understood in subsequent sections, we hereby shift the focus to the "features of schematising". In doing so, we divide the concept of schematising into two dimensions, namely *static* schematisation and *dynamic* schematisation.

Both of these aspects of schematisation should be given consideration. However, we feel that dynamic schematisation should be particularly emphasised in early childhood because it presumes a higher level of understanding of relationships. This understanding is necessary to create graphical representations of action, change, transformation, and so forth, and because most mathematical activities are based on the use and construction of such dynamic schematisations. Carruthers and Worthington (2003) underscore this assumption as well.

Very little published literature differentiates between static and dynamic schemes. Carruthers and Worthington (2003) have drawn upon Hughes (1986) to establish their taxonomy of schematisations. They distinguish different types of schematisations on the basis of the *forms* the schematisations take (graphic representations, approximations, mathematical symbols, etc.) and the *functions* of the schematisations (envelopment, trajectory, enclosure, transportation, connection, rotation, transcending a boundary, oblique trajectory, containment, transformation). We believe that these two types of schematisations can be classified in a more generic way. Some of these schematisations represent a status quo or state of equilibrium and thus do not attempt to be anything more than that, while others represent translations, like movement, or transformations, like change or growth, and thus attempt to reflect changes in form or position. Hence, we use a dichotomy of possible scheme types whereby we distinguish between static and dynamic schemes.



Figure 1. Dynamic schematisation. Two children tried to represent that the researcher took a red marble out of a pot and put a green one in.

Figure 1 shows dynamic schematisations. An example of static schematisation is shown in Figure 5.

The pictures in Figures 1 and 5 show that these children were able to graphically represent their observations schematically. (See Question 1 of the schematising test).

Although numerous examples of schematising images can be provided, we have chosen to use a table, rather than additional drawings, to demonstrate the most important differences between dynamic and static schematisations.

We think the development of dynamic schematising should be emphasised in early childhood education, because this asks for understanding of relationships (as can be seen in Table 1). Table 1 demonstrates that static schematisations only show the state of something (a status quo), whereas dynamic schematisation includes *symbols which suggest processes* (like changes, movements, transformations, transcriptions). The content of the symbols is important in the latter type of schematisations. This understanding of the content of symbols is necessary in order to represent action, change, or transformation in such a way that everybody can understand what you mean. Since mathematical activities are based on the use and construction of relationships and transformations (e.g., transforming 5 into $2 + 3$), we suppose that opportunities to represent relations, change, transformations, and so forth, are an important prerequisite for the improvement of mathematical thinking.

Methods

Design

We used the design-based research approach for our research project (see Bakker, Doorman, & Drijvers, 2003; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). During one school year in the second grade, we introduced schematising activities in the experimental condition, with the help of a teacher trainer and in collaboration with the teachers. According to the methodology of design experiments (see, e.g.,

Table 1. Differences static and dynamic schematisation.

Dimension	Static schematisation	Dynamic schematisation
Transformation	Similarity between schema and object	Drawings representing action; change, processes, movement, transformation
	Use of words and letters referring to individual objects	Drawings representing a thought line/reasoning in other process symbols
	Being able to explain or carry out the relation between drawing and object, sign and meaning: equivalence	Being able to explain or carry out the relation between drawing and object, sign and meaning: transformation
Relation	One symbol per counted object	Symbols representing movement or modifications and the objects involved
Narrative structure	Narratives as descriptions of states	Narratives with a “plot”
Use of operators	Use of numerals and symbols referring to individual objects	Making use of operators as productive symbols that generate new meanings
Meaningfulness	Mechanically associating symbols (reproducing, rote learning)	Bringing together in a meaningful whole the different notions associated with the sign concerned (relating, arguing)

Cobb et al., 2003), it is required that teachers, pupils, researchers, and teacher trainers intensively work together in order to develop activities that could call for some form of representation in children. The teacher trainer involved in our project assisted teachers with helping pupils in the experimental condition to schematise. It is inherent to the Vygotskian view on education and the design-based research that each situation is tailored to individual needs (Kozulin, Gindis, Ageyev, & Miller, 2003). For example, two children have difficulties with drawing their building, but the one child needs other hints than the other child in order to solve the problems, and therefore we choose to describe the paradigm of our intervention instead of detailed descriptions at length of each activity in our project (see also the section on the intervention process).

Research setting and participants

Three schools, all using a Vygotsky-based approach to education, thus Developmental Education, introduced schematising in their early childhood education for one school year. The experimental group comprised 75 pupils. Three other schools, also committed to the developmental education approach, functioned as the control group and therefore did not introduce schematising in early childhood education. This group comprised 58 pupils.

The schools were selected based on previous contacts, their willingness to participate in the experiment, their approach to education, and their contact with a teacher trainer involved in our project. The six schools were divided among three research pairs. The pairs were matched according to the amount of time a teacher has worked using the Vygotskian view of education, their student population, the number of students participating, and their location (urban or rural). All schools

that participated were public schools. Two of the schools were situated in a large city (Amsterdam), two of them were located in medium- to large-sized cities, and the remainder was situated in villages close to one of the larger cities. Two of the schools (one in the experimental group and one in the control group) were composed predominantly of children from a non-Dutch background. As a result, the descriptions provided here cannot be generalised to all Dutch schools. However, we considered the comparison between the two groups to be sufficiently valid given the similarity between the two groups with respect to the school population, the degree to which teachers were prepared for this project, the use of curriculum materials, and the length of time the teachers had worked with developmental education.

The intervention process

For our research project, we requested the help of a teacher trainer whose work is also based on the Vygotskian concept of development and education. Instead of imposing a ready-made programme on the curriculum, we introduced the teacher trainer to the teachers in the study as part of the experiment. It was the teacher trainer's job to guide teachers' activities towards the inclusion of schematisation. In this sense, the teacher trainer functioned as an "interpreter". He was able to translate the theoretical concepts of the research project into practical strategies for the introduction of schematising in the classroom. Because of his work, we were able to alternate between thought experiments (theory-based prototypes of educational situations and their possible outcomes) and teaching experiments, designed to evaluate the value of these prototypical situations in real classroom situations (see Freudenthal, 1991, p. 160).

The teachers involved in our research groups adopted the concept of Developmental Education as a basis for their own teaching. We endeavoured to ensure that the different treatment conditions resulted in a difference between the experimental group and the control group as doing so could determine if introducing schematising in early childhood does indeed have a positive effect on later learning outcomes. The teachers involved in our experimental setting had received earlier instruction from our teacher trainer on developmental education but not on schematising. Prior to the start of our research project, the teachers had not been specifically trained to use schematising activities with pupils. During the intervention period, activities were organised so that they were interesting to the pupils and contained relevant cultural meanings. The teacher participated in these activities as a partner in the negotiation of meaning and also identified or created teaching opportunities to help children further develop their actions and abilities. The teacher also provided insight into children's development and linked this to plans for further teaching (Fijma, 2003). Because the teachers and the teacher trainer were familiar with working on these qualities and underscored the Vygotskian way of teaching, we felt this was the best way to give structure to the experimental setting. Researcher and teacher trainer both found the teachers involved were sufficiently skilled in teaching schematising: The teaching process was carried out according to the intended goals of the intervention process.

The teacher trainer visited the three experimental schools each month in the experimental year of our research project when the children were in Grade 2 (age 5 to 6). After each visit, the researcher and the teacher trainer reflected on their

experiences in the classroom. After this reflection, they were able to improve the intervention.

The teacher trainer taught the teacher and pupils to create relevant schematising activities based on play activities. An example is as follows: While children construct a building, the teacher could encourage the students to make a design of the building. The design of the building could then become a dynamic schematisation if the teacher suggests that the children describe the steps required to make the building. However, the teacher would first have to become accustomed to the idea that you can enrich a simple “building” activity by encouraging children to create a design of the building. The next step would be to teach the children how to transform a static schematisation into a dynamic schematisation.

Our teacher trainer also visited the control schools each month in the first year of the study. However, there was a marked difference in his interventions in the control group classrooms as compared to the experimental group classrooms. Unlike the experimental groups, where the teacher trainer placed emphasis on dynamic schematisation and reflection, no such activity was conducted with the control group. In short, while the teacher trainer attempted to make the learning process of schematising as complete as possible in the experimental group, this was omitted in the control group.

Instruments: the schematising test

At the end of Grade 2, we administered the researcher-created “schematising test” that was intended to measure how schematising activities proceeded at the end of our intervention period. One of the researchers videotaped the “schematising tests”. In this test, the children were asked, one by one, to solve three schematisation problems. Since children at the age of 5–6 are not able yet to read or write, we created a situation in which children were observed and filmed, and we made use of oral testing. None of the children was familiar with any of these questions, because the questions did not follow from play activities. In this way, children were also tested on their transfer skills. Because the experimental condition practised with dynamic schematisations, we expected them to perform better on our test and to be better able to show transfer skills as compared to the control condition. The questions were as follows:

Question 1

The researcher showed the child a little pot with a red marble in it. Next to the pot lay a green marble. The researcher asked the child to watch and see what happens. The researcher then took the red marble out of the pot and put the green one in the pot. Then he asked the child to draw what he or she saw.

The resulting graphical representation was expected to resemble the following illustrations (Figure 2).

Question 2

The researcher explained that, in this drawing, the child would be able to see a triangle made of three little bars (see Figure 3). Then the child was given three bars. Following this, the child was asked to look at the drawing and show the researcher what should be done with the bars.

The child should have noted the purpose of the two arrows, which illustrate that the two sides of the triangle should be moved to the bottom of the diagram.

Question 3

The researcher told the child about a little mouse which had been walking around the classroom. The mouse had been following the route illustrated by the picture in Figure 4. The researcher asked the child to describe the route the mouse took and asked if the child could walk the same route in the classroom.

Data analyses

Before our analysis of the video footage, we had to determine the reliability of our scoring system. As the nature of the instrument basically requires observation and interpretation, we decided to ask a second, independent observer to analyse the videos. A second observer analysed the videos in order to establish observer agreement with regard to this test. Cohen's Kappa was found to be 0.93, meaning that there was sufficient agreement between the observers.

For the analysis of the "schematising test", a list of criteria was developed by the researchers to score the answers on the test. In order to obtain a way of gleaning the performance level of the children from our video data and to process the data statistically, we constructed a rating scale. The test consisted of three questions, and children could obtain either zero, 1, or 2 points for each question. Two points were given for correct answers (the child interpreted the situation correctly and he acted



Figure 2. Answer on Question 1 of schematising.

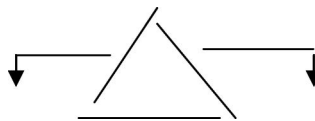


Figure 3. Question 2 in schematising.



Figure 4. Question 3 in schematising.

correctly), 1 point was awarded to answers that showed correct action OR correct interpretation, and a zero was awarded if a child didn't give a correct interpretation nor a correct action. The maximum score was 6 points if each of the three questions was answered correctly. Once these data were collected, the mean scores of each condition were compared, using the *independent samples t test*. The Levene's test for equality of variances was also performed. Because we expected our experimental group to perform better than our control group, we tested for one-tailed significance. Finally, we were also interested in the effect size (d), which we calculated with Cohen's (1988) formula: $d = M_1 - M_2/\sigma$.

Results

It is evident from the videoclips that children from the control group typically showed static schemes that showed the results of what happened, whereas children from the experimental group often made dynamic schemes using symbols (e.g., arrows) that suggest processes (transformations, movements).

Table 2 displays the results of the "schematising test". An overview of the total experimental group compared to the total control group is demonstrated in the table.

Based on the data presented in Table 2, we can conclude that there was a significant difference between the experimental group and control group's performance. The size of the effect is 1.4, which is a large effect (see Cohen, 1988) in favour of the experimental group.

Interpretation of the results

In order to clarify the differences between the test results relating to both groups, some illustrations and descriptions of the way the children dealt with the questions are in order. While watching the videos, we noticed some remarkable differences between the two groups. Notably, none of the children in the control groups were able to solve the first question on the test. It seemed to be a difficult question for the experimental group as well. However, in contrast to the control group, a number of children from the experimental group were able to solve the first mathematical problem. The most interesting part of the test was that the children only described the final product, not the process.

- Researcher: Did you draw what I showed you?
 Child: Yeah ...
 Researcher: And was this all that happened?
 Child: Yes, you threw the red marble out of the pot and put the green one in and that is what I drew.
 Researcher: Ok.

Table 2. The experimental group ($N = 35$) compared to the control group ($N = 19$) on schematising.

Condition	M	SD	df	F	t	p
Experimental	3.43	1.481	52	1.054	4.558	0.00
Control	1.74	1.195	44.258			

This example represents about 80% of all the interactions on the videos. Most of the children only drew the *outcome* of the process and were not able to draw the *process* itself. They were meant to use arrows to show movement or action, but this dynamic form of schematising seemed very unfamiliar to most of the pupils in the control group. Figure 5 is thus an example of static schematisation, since it does not show symbols that suggest processes. The child tells us about movement but did not symbolise it.

The second question was also very difficult for control group subjects. The child who solved this problem needed a long time to process the question and, only after some further interaction with the researcher, finally was able to come up with the correct answer. For instance, in contrast to the experimental participants, control group participants did not recognise the arrows in the drawing and, if they did, they did not know the function of the arrows. The experimental group did not appear to have much difficulty solving this problem. It is also important to note that the interactions during these questions were very interesting interactions, as illustrated in the example below:

- Researcher: Do you see this drawing?
 Child: Yes.
 Researcher: And do you see these bars?
 Child: Yes ...
 Researcher: Now, can you show me what is happening in this picture, by using these bars?
 Child: Yes.
 Researcher: Ok, well show me.
 Child: The roof is falling down.
 Researcher: Can you show that?
Child: The child moves the bars – all the bars
 Researcher: And how did you see that? What on the picture makes you think you had to do this?
 Child: *Pointing to the arrows.* This one is falling down and this one is falling diagonally and the other one moves away
 Researcher: Why is the other one moving away?



Figure 5. An example of static schematisation.

- Child: Because the roof is collapsing!
 Researcher: But how did you know the roof was going to collapse?
 Child: Because he is going this way ...
 Researcher: And did you see something else besides the roof?
 Child: It is going diagonally.
 Researcher: And do you see something else in the picture?
 Child: That it is going a little bit wrong.
 Researcher: Yes, you see the roof, but you also see something else don't you?
 Child: Arrows!
 Researcher: Yes! And what do those arrows mean?
 Child: That the roof is falling down!
 Researcher: Exactly!

This example shows that the child recognised the arrows and that he knew what the function of arrows can be. However, in this case, the child only thought of a collapsing roof. The child knew what the arrows signified but was not able to describe the process.

We considered the third question to be the easiest of the three problems and therefore expected both groups to be able to complete it correctly. However, surprisingly enough, only a few (five) of the control participants succeeded in answering this question, and most of the experimental group subjects did eventually manage to solve it. It was remarkable that all the children were able to indicate which way the mouse walked, but occasionally, the children thought abstractly and could not translate the solution into the classroom context. They thus described the correct route while they walked the opposite route.

Discussion and conclusions

The goal of this study was to demonstrate the importance of introducing schematising in early childhood and to investigate if children could learn schematising skills through educational experiences. We attempted to provide support for our hypothesis using a Vygotskian perspective and by providing an overview of the results of our empirical study.

With regard to the "schematising test", we found that the pupils in the experimental group had a mean score that was almost 2 points higher than the mean score of the pupils in the control group. This difference is significant and relevant. This outcome cannot be a result of "automatic" cognitive development, as the performances of the control group on the schematising test were considerably poorer.

As a result of our study, we also conclude that children do indeed profit from the introduction of schematising activities in early childhood as they emerge from play activities in the way Vygotsky (1978) suggests. If we want to try to teach children the schematising abilities, we have to make sure that this is meaningful for them. Otherwise it will not be functional to teach this. We expected our experimental group to achieve better results on our test and to be more successful in performing dynamic schematisations. This hypothesis has been supported by the results of our study presented in this article. Nonetheless, it is important that further research be conducted on the long-term effects of schematising in the follow-up of this study (see Poland, 2007).

The confirmation of our hypothesis may seem self-evident because we “trained” the experimental group to perform well on our test. To put it more precisely, one could state that we were teaching towards the test. This is true, but it is absolutely not a trivial outcome. It demonstrates that young children can indeed profit from this type of semiotic activity. Obviously, this ability does not develop spontaneously at the age of the pupils we tested. Therefore, it should be part of early primary education, as could be expected from our cultural-historical theoretical framework. In our intervention study, we introduced schematic representations as a tool for communication and thinking in the context of children’s play. The results of our study demonstrate that play can indeed be used as a context for learning and appropriating new tools, even as abstract as schematic representations. This is consistent with research outcomes of Hughes (1986) and Venger (1986).

We reached our conclusions on the basis of observations of children’s performances, which might be biased. Testing young children at the age of 5 and 6, though, has some restrictions, due to the limited ways of communication with these children. For instance, these children are not able to read or write, and, therefore, tests have to be administered individually or in small groups. Moreover, tests have to be oral tests and may not take too long. Therefore, a test can only consist of a few items, and observation instruments have to be developed. In order to control for the potential bias, we asked a second, independent observer to score the results. The individual oral test was videotaped and the inter-observer agreement turned out to be more than sufficient. We may conclude that our results are based on valid interpretations of the videoclips.

In this study, we found that we were able to create a group which distinguishes itself of other children (control group) with regard to schematising. We predict that this could have a positive influence on children’s future mathematical learning outcomes.

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